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Computer Science in Secondary Schools in the UK: Ways to Empower Teachers

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Abstract. The recent move towards more Computer Science in school in the UK has obvious implications for teacher education, both for in-service and pre-service teachers. In England and other parts of the UK we have seen an unprecedented rate of change in the way that curricula are changing from a focus on learning to use software applications to the introduction of Computer Science throughout primary and secondary schools. In this paper we describe some of the challenges that we have faced, the progress made in the integration of CS, and the support provided for teachers in their professional development. Current developments seek to support teachers with varying needs in a holistic way and we propose a transformational model of professional development [1] for CS, both for in-service teachers as well as forming the basis of new teacher training programmes.

Keywords: CS teacher education, teacher professional development, CS secondary school education

1 Introduction

We are experiencing rapid change in England and other parts of the UK in the curriculum for Computer Science and ICT. These changes have been in-part driven by the advocacy work of the Computing At school (CAS) group, pressure from higher education and from industry. The climate of change has generated national press interest; the result is substantial change to the curriculum and also to the entry criteria for future teachers of Computer Science. These changes are very exciting and there is an atmosphere of great enthusiasm and anticipation across the UK from teachers who are keen to seize the opportunities offered to enhance and extend the current curriculum. However, not all teachers feel qualified to do this and many are in need of support. Finding ways to support the re-skilling of many teachers in the UK to be able to teach CS in school is key to any implementation of a new curriculum.

2 Developments in the UK

The changes we are seeing now in CS education in school are being prompted because two decades ago changes in the curriculum shifted the focus from Computer Science-related topics to Information and Communication Technology (ICT). ICT has a considerable emphasis on the use of software applications and the application of technology, and does not cover any computational thinking or programming [2]. In addition, the early 2000s saw an large increase in the availability of vocational qualifications in ICT [3] and a lack of options for pupils who wished to study CS, together with a confusion about what the subject was actually about. However this situation in the UK is currently being reversed. The establishment of Computing At School (CAS), an organisation formed in 2008 to promote CS education in the UK and support CS teachers, has had a significant impact on the development of a new curriculum and revised understanding. Its efforts have been augmented by the effect of a lecture by Eric Schmidt, Executive Chairman of Google, criticising the lack of computer science education in UK schools [4]. Eric Schmidt, Chairman of Google, was highly critical of the standards of computer science (CS) education in British schools:

> *"We need to reignite childrens passion for science, engineering, and maths ... I was flabbergasted to learn that today computer science isnt even taught as standard in UK schools. Your IT curriculum focuses on teaching how to use software, but gives no insight into how its made. That is just throwing away your great computing heritage."*

The Royal Society followed with a report entitled Shut Down or Restart: The way forward for Computing in UK schools [5]. The report, a result of an 18 month consultation, described the teaching of CS in many schools as "highly unsatisfactory", recognising that continuing professional development (CPD)[4] for teachers was insufficient. In this regard, the report states:

> *"There is a lack of support for CPD for Computing and Information Technology teachers that deepens subject knowledge and subject-specific pedagogy, particularly in Computer Science. This needs to be addressed – it is important that teachers have access to good quality CPD, particularly given the lack of specialists"* [5]

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The Royal Society report's recommendations included:

- increasing the number of teachers trained to teach Computer Science
- improving in-service training for teachers
- providing more technical resources for schools.

[4] We use both the terms Continuing Professional Development (CPD) and Teachers' Professional Development (TPD) to mean professional development activities involving in-service teachers.

There have been further changes, at least in England, following on from these events. The programme of study for ICT, with its focus on the use of software applications, has been discontinued, pending a curriculum review to be implemented in 2014. New teachers are to be trained to teach Computer Science and not ICT [6].

It should be noted that the "UK" includes Scotland, Northern Ireland and Wales, as well as England, and these countries have their own curricular and their own awarding bodies. Although Eric Schmidt gave his influential speech in Edinburgh, Scotland is the one devolved country which retained Computer Studies as a subject and trains teachers to teach Computing who must have be Computer Science graduates. In the other parts of the UK, ICT has dominated.

3 Computer Science and Teacher Professional Development

3.1 Learning from the experiences of others

It is clear from the above that the changes in the UK are being welcomed eagerly by some Computer Science teachers. However, not for all. There are many challenges to be overcome in establishing an effective model for professional development that is long-lasting and not just a quick fix. Change in schools and in attitudes is a long term process [7]. In terms of training new teachers, ICT has not been an easy subject to which to recruit; it is hoped that proposed changes to the curriculum will attract more well-qualified entrants to the teaching profession.

In establishing support for teachers, the UK has much to learn from other nations. Much has been written about the development of the K-12 curriculum for Computer Science in the USA and also the national programme for Computer Science in Israel. The Israeli programme consists of the four elements of: a mandatory CS license, a CS teacher programme, a CS curriculum and CS Education research [7]. This is a structured programme with clearly signposted content. The work by the CSTA in the USA has established a curriculum that is comprehensive; although it is still the case that the uptake of Computer Science in the curriculum in the USA varies between states [8].

In Israel, a Computer Science degree is essential for entry into the profession. However, Ni and Guzdial write that in the USA there are too few teachers with a CS degree [8]. The CS10K project is attempting to remedy that with the aim of establishing 10,000 teachers in 10,000 schools teaching the new curriculum by 2015 [9]. Although the UK is still developing a curriculum, with the assistance of experienced teachers, academics, and teacher educators, and it will allow for greater flexibility than that which exists in other countries, we have similar goals to recruit, retrain and empower a substantial body of CS teachers for school.

In the next section we turn to the types of TPD and their efficacy in our situation.

3.2 Types of Teacher Professional Development

There is a wealth of research on TPD spanning several decades, including hundreds of individual studies of different types of TPD and the evaluation of TPD. Teachers can participate in many hours of training or other prescribed TPD in school or college and take up external courses in order to improve their own skills in teaching and learning but sometimes actual change is difficult to achieve, particularly as *"change is a gradual and difficult process for teachers"* [10]. As Bell & Gilbert report [11], sometimes even the most well-intentioned efforts to change do not succeed:

> *"... many teachers, even after attending an in-service course, for example, feel unable to use the new teaching activities, curriculum materials or content knowledge to improve the learning of their students ... Many teachers are aware of this pattern and feel frustrated in their attempts to change"* [11, p.9]).

There is the question of the content of the professional development we should be offering. Particularly relevant is the balance between subject matter knowledge (SMK) and pedagogical content knowledge (PCK) as described by Shulman [12] and put into the context of Computer Science Education by Armoni [13]. Armoni emphasises the importance of learning how to teach CS as well as a teachers own understanding of the subject. Another type of knowledge is curriculum knowledge and it will be important that our model incorporates all three of these aspects in supporting and empowering teachers.

Another issue is how to structure professional development programmes. Kennedy [1] considers a wide range of models of TPD (which she refers to as CPD), and proposes a framework through which they can be analysed. She defines nine different categories of CPD and places them on a spectrum in terms of their *"potential capacity for transformative practice and professional autonomy"* [1, p.236].

Kennedy's nine categories of professional development are shown in Table 1. These are divided into three types: transmissional, transitional and transformative. She discusses some of the drawbacks of the transmissional approach, but in terms of SMK knowledge [13], it may have a part to play. The transformative category is seen as the goal for professional development programmes, and incorporates aspects of the other categories.

Table 1. Kennedy's models of Continuing Professional Development [1]

Transmissional	**Transitional**	**Transformative**
training	standards-bearing	action research
award-bearing	coaching/mentoring	transformative
deficit	community of practice	
cascade		

There is a notion that the transmissional type of TPD is less successful because it does not offer sufficient teacher autonomy. Fraser, Kennedy, Reid & McKinney posit that *"Formal planned opportunities, which are essentially transmissive, are unlikely to result in transformative professional learning for teachers, because they attend primarily to occupational aspects of professional learning"* [14, p165]. In contrast, they consider that transformational learning is more likely to take place where the opportunities for learning attend to the personal and social aspect of professional learning. However this view is rather narrow as good training will not necessarily be transmissive, if the trainer acts as a facilitator and the training is a two-way process between teacher and trainer. What is being identified here is that the training, if in a formal setting, may not be applied and used soon enough to be embedded.

Collaborative professional development programmes can be very effective. This can be defined as *"teachers working together on a sustained basis and/or teachers working with LEA or HEI or other professional colleagues"* [15] . In all but one of 266 studies of collaborative TPD reviewed by Cordingley, Bell, Rundell & Evans [15] there was a definite teacher improvement as a result.

Another type of TPD identified by Kennedy is the community of practice, where there is a joint enterprise, mutuality and a shared repertoire of communal resources [16]. In practice, teachers working together towards a common goal, for example, implementing a new strategy, who share their experiences, talk the same language, and are willing to learn from one another, can be said to be a community of practice.

Being mentored or coached is another way that a teacher can develop professionally. With a peer coaching model [17], teachers of equal status work together; in contrast, mentoring assumes that the mentor has a higher level of expertise than the mentee [18]. Mentoring may be less likely to be transformative than coaching, whereas the coaching experience is designed such that the coachee is able to solve their own problems and thus become empowered to be able to effect change.

As Lipowski, Jorde, Prenzel & Seidel report [19], there is also a need for institutional support within TPD. In a recent study, experts from a range of countries report an urgent need to *"reform existing insititutional conditions, including existing cooperation or coordination structures between institutions involved in the TPD system"* [19, p694]. The impact of effective TPD can be directly linked to school improvement. Opfer and Pedder report [20] that teachers in the highest performing schools reported participating in professional learning activities with higher levels of effectiveness: they were of longer duration, were more active, and teachers shared what they had learned with colleagues more often. This demonstrates that achieving good-quality TPD can affect the performance of the school. An Ofsted[5] report [21] on professional development (PD) supports this by stating that the weakest link in the chain is the way the schools evaluate the effectiveness of their PD activities.

[5] Office for Standards in Education, Children's Services and Skills

There is a need to be aware of the identity of teachers as explored recently by Ni and Guzdial [8] who remark that from their small sample of teachers who identify as CS teachers *"they all saw the evolving nature of CS and would like to learn more to keep updated and teach these courses better. In addition, since they were isolated, they all wanted to keep connected and collaborate with other teachers to address challenges in teaching CS."*

4 Challenges in the UK

We can now turn to key developments happening in the UK. Making quite significant changes to the curriculum faces us with various challenges. These can be identified, in line with the key points in the Royal Society report. as:

1. **Upskilling existing teachers**
   Teachers in England, Wales and NI have been trained for the last 20 years to teach ICT without Computer Science. A few teachers teach Computing to the 16+ age group so are able to easily adapt to these changes. Others may have not used their degree in teaching for many years, or may have a degree subject that did not include any Computer Science. With changes being introduced already, there is an urgent need to provide professional development in a range of forms for these teachers. However, schools do not have an additional budget for this, and time is not easy to find in an already busy role.
2. **Training new teachers**
   It has not been easy in recent years to recruit sufficient teachers to teach ICT in schools, particularly those with a degree containing some Computer Science. The challenge is two-fold: to attract well-qualified teachers into the profession and to offer appropriate training for new teachers to ready them for the curriculum changes.
3. **Curriculum and resources**
   Teachers need resources to enable them to teach new aspects of the curriculum. There are many issues around who should develop these and the nature of their dissemination. The curriculum still needs to be specified and currently there is no programme of study in England to guide teachers in any way. There are many resources available but teachers need to have sufficient subject knowledge to understand them.

The challenges we have identified are similar to those identified in a recent study carried out across 23 different countries, where experts and teachers identified the problems facing CS teacher education [22].

In this paper we will not consider issues of curriculum and resources in the UK. As Cuny states:

> *"Curriculum isn't our biggest challenge. The biggest challenge will be developing effective teacher preparation and support, and scaling it to reach 10,000 teachers. Few schools today have teachers with any formal*

CS training. The computing community must launch an unprecedented effort to prepare teachers, working with in-service as well as pre-service teachers, and in both traditional and alternative certification programs." [23]

As stated, the curriculum in England is currently being redesigned; a draft programme of study is being proposed for ICT that will incorporate Computer Science across all age groups. Teachers across the country are sharing resources via networks and discussion groups. Undoubtedly this is a process that needs some organisation and streamlining but the moves in the UK are moving away from a tight and prescriptive curriculum towards an empowering of teachers to adapt their teaching to suit the needs of their own students and school environment. However teachers can only be empowered in this way if they have the confidence in their ability to teach the subject. As Cuny states, focusing on ensuring that we have sufficient teachers is essential at this time.

In the next two sections, we will look at the efforts made to improve the skills of teachers and briefly address progress in pre-service training.

5 Upskilling existing teachers

5.1 Survey of teacher needs

Across the UK, a combination of local (bottom-up) activities and national (top-down) initiatives are emerging. To inform the development of initiatives, we carried out a survey to establish what teachers want from a professional development programme. This took the form of an online questionnaire, with a combination of closed and open questions. The closed questions used a 4-point Likert scale. The questions were centred around three main areas:

- What type of skills and knowledge do teachers lack?
- What form of professional development courses work best?
- What factors affect the ability to participate in professional development

The survey was distributed to teachers who had expressed an interest in CS by attending professional development courses/training, or by subscribing to the CAS group. 86 teachers responded, of which 85% taught in a secondary school, 6% in primary schools and 9% in post-16 education or other institutions. 33% of these teachers stated that they hadn't received any professional development in CS in the last two years, whereas other teachers had either participated in one or more courses or were enrolled on a programme leading to some accreditation.

5.2 Results

The first part of the survey related to the actual areas with which teachers needed support. Teachers ware able to select as many topics as they wished. Whilst the expression of a need for skills in computer programming was expected, the results

showed (Figure 1) that 'guidance on ways of teaching Computing', in other words the pedagogical or PCK knowledge [12], represented the greatest need for teachers (71% of teachers). This was closely followed by a need for resources and tools for teaching CS (64%). The least number of responses were received for teaching post-16 courses (38%) (the survey numbers only included 62% of teachers who taught this age group), and guidance on teaching a particular curriculum or specification (39%).

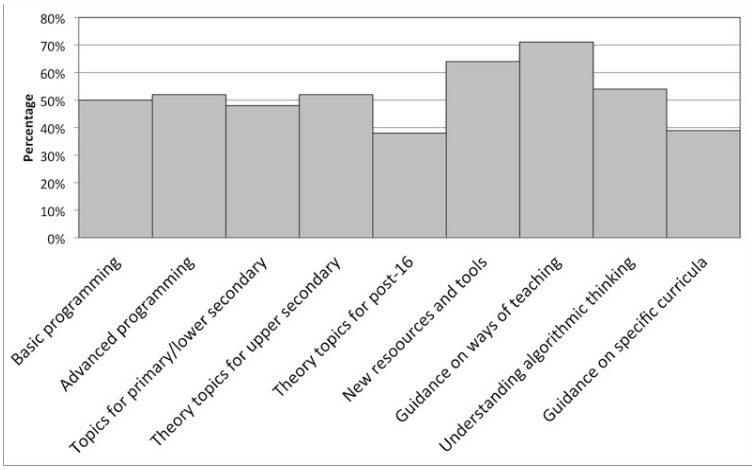

Fig. 1. Relative need for CS Topics for professional development

One teacher commented that: *"Workshops on the technology have largely been time-wasters for me. It's the pedagogy I need."*. Another comment was that there was a need for *"Lesson Plans and Resources that can be followed and taught easily by teachers"*. Some teachers had had experiences of courses that had not covered what they needed: *"Courses which don't live up to their objectives or which are poorly targeted (i.e. wrong audience)"*, whilst others might have been incorrectly pitched: *"Just learning the basics of something again when you already know more and have been using these skills already. It makes you switch off and wastes the entire session."*

The next area of the survey relates to the form that the professional development should take. Table 2 shows the relative popularity of different formats of professional development events and provision. These have been ordered for clarity, and show the percentage of teachers who thought each type of delivery was either helpful or most helpful (teachers could choose as many options as they wished). 80% of teachers state that they would find it helpful to attend a one-day workshop in school time as part of their professional development. There may be issues around this as often teachers report how difficult it is to be released from their teaching duties. The survey did not ask teachers about the applicability of the workshop which would have been useful follow-up given this response. In

One-day workshop	80%
Working with experienced teacher	69%
Resources/on-line forums	57%
Online/self-paced course	54%
Intensive course in holiday	54%
Within own department	46%
Evening class	45%
Action research project	41%
Twilight course	33%
Weekend course	32%

Table 2. Which type of professional development is helpful/very helpful?

contrast fewer teachers were willing to attend twilight, evening classes and weekend courses. However these courses do exist and are popular with some teachers. Teachers are clear that they benefit from the networking available from meeting other teachers. One teacher said that the most useful thing was: *"Regular get togethers facilitated by experienced teachers/lecturers updating knowledge and networks."*. Another valued *"Chances to share ideas with colleagues, to try out new software and to discuss approaches to teaching a topic."*

Another aspect of the survey related to the factors that affected the school's and the teachers' willingness to engage with a professional development programme. This is shown in Figure 2. Not surprisingly time was a significant issue both for teachers and schools.

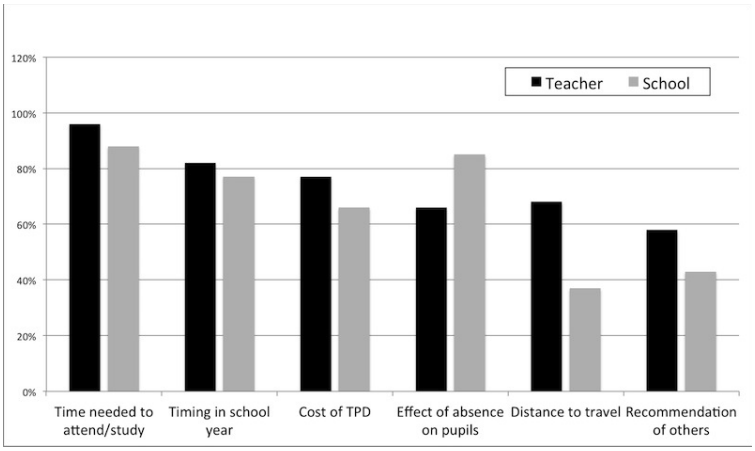

Fig. 2. Factors affecting school and teachers' choices of good TPD

One teacher commented that *"Schools need to be made to see that re-training is crucial to success in this transition and that it is not optional otherwise staff will not be able to deliver the courses"*.

In summary, the survey has informed future developments with a rapidly emerging situation. The government is forging ahead in England with radical changes to teacher training and some incentive payments for highly qualified CS graduates.The following initiatives describe some of the ways we are beginning to address the needs of teachers outlined above.

- Training courses - the Python School model
- Classroom support for teachers - the Digital Schoolhouse model
- CAS Master Teachers
- The Network of Excellence
- Local hub development

One of the underlying principles of the way in which we are moving forward is a using a "grass roots" approach. Enthusiastic practitioners have ideas which they share with others. Experienced teachers support other teachers. More formal training courses are set up, but these are mostly delivered by teachers based on their own experiences. Examples of this model are the Digital Schoolhouse[6], training courses run by teachers for teachers, and the CAS Master teachers programme.

5.3 Training courses - the Python School model

Training courses are increasingly being offered by teachers and universities across the UK. One example are the courses offered by Python School[7] using a blended learning model. These courses are of two types: programming courses with some emphasis on subject knowledge and some on pedagogy; and courses around curriculum areas which combine the theory of the subject, modelling of approaches to teaching and some curriculum guidance (all three of the areas described by Armoni [13]). In terms of the format of these courses, different formats have been implemented including evening classes, twilight courses, intensive courses in the holiday period and two-day courses. The courses are offered by two of the authors and run face-to-face in the East of England, with website materials to back up and reinforce the class material. The website also has hundreds of registered users who access the materials purely online.

The twilight and evening classes have been aimed at existing teachers who may find it difficult to attend an intensive course as it requires so much time away from school, and the intensive course at trainee teachers who have just finished their initial teacher education. In a third type of delivery, more advanced courses are run on Fridays and Saturdays during a mid-term break. In all these approaches the delivery has been by current teachers/teacher educators who have experience in teaching CS in a school environment. It has been assumed

[6] http://www.digitalschoolhouse.org.uk
[7] http://www.pythonschool.net

that current practitioners are best placed to explain how to deliver this content to students and to avoid overcomplicating the process with unnecessary detail. This fits in with our emphasis on using experienced teachers to support other teachers.

Respondents gave enthusiastic feedback on their experience of the course, for example: *"My expectations have been exceeded. I've learned more about Python than I thought or hoped and the computer science lessons have been very thorough."*. Teachers were asked to rate their confidence levels before and after the course and the average confidence level rose from 2.9 to 7.7 from the 10-week program. Some teachers did find the course very challenging: *" [I would like] ... more time programming or do this first as by the later time I was really tired and found it more difficult to focus"*. Attending training after a long teaching day is demanding on teachers.

5.4 Classroom support for teachers - the Digital Schoolhouse model

Within this initiative, teachers visiting the Digital Schoolhouse project with their pupils are provided with continued professional development opportunities through team teaching [24]. This is achieved by the Digital Schoolhouse teacher encouraging the visiting class teacher to take an active role in the lesson at the start of the day. To develop enthusiasm and reassure pupils, the Digital Schoolhouse teacher asks the visiting class teacher to help; the teacher is then used to model activities whilst using the computer at the front of classroom in view of the pupils.

Using this framework, the project regularly receives excellent feedback from both staff and pupils, with teachers feeling more confident to deliver similar lessons in their school and opting to use their next Digital Schoolhouse booking to experience a different ICT and CS lesson. They also gain confidence through using CS lesson resources freely available from the Digital Schoolhouse website. This approach to teacher training has also recently been incorporated into the Technocamps Project in Wales[8].

5.5 Computing at School Master Teachers

Another approach is to fund a small but significant group of "CAS Master Teachers". To support the universities with developing and delivering teacher training materials that meet the needs of local schools, CAS is recruiting Master Teachers to form a local provider team. Master Teachers will work with universities in the Network of Excellence. In the medium term it is hoped that this will create CS departments who are more aware of the needs of local schools and how to meet them as well as a national network of advanced skills teachers in CS. These 'CAS Master teachers' will be responsible for the elivery of CPD to schools in their region working in association with HE and industry. The structure and content of the courses can be determined by the local provider team but will be

[8] http://www.technocamps.com

influenced by the CAS Curriculum, and will point to suitable resources on the CAS Community site. Each resource would be mapped to the points of study in the CAS Curriculum and in the long term ensure curriculum coverage.

5.6 Network of Excellence

The Network of Teaching Excellence in Computer Science is an initiative that has been set up by CAS and BCS Academy of Computing, the learned society which is dedicated to advancing Computing (CS & IT) as an academic discipline. It is designed to utilise and formalise the hub system set up within CAS, with schools and universities across the country registering to support one another. The ambitious aim of the network is to establish CS teaching in at least 1000 schools by 2015. Initially one university will support twenty-five secondary schools. Using the university as a central point of reference it is hoped that they will be able to better identify and adapt their support for the needs of the local schools. To make this model sustainable, schools will then support at least one other school. In 2012, over 500 schools signed up after the first announcement, so CAS is well on its way to meeting its target.

5.7 Local Hub development

Teachers need a professional identity, as explored by Ni and Guzdial [8]. In the UK, this can be supported by CAS through hub meetings where teachers' interest in Computer Science is validated by the Community of Practice [25].

Local hub meetings are held after school for groups of teachers in areas across the UK to discuss CS teaching issues. Guest speakers are invited to share their own areas of expertise. Teachers also share their experiences and resources. Typically, hub meetings take place two or three times per year with about 20 to 30 attendees, although this varies. There are more than 40 hubs across the UK, and these provide a community of practice for participating teachers where they can discuss issues relating to teaching Computer Science in school and find out about new developments and resources. Hubs are also setting up their own localised professional development sessions, for example, learning to use Scratch or Python.

6 Initial Teacher Education

Initial teacher education can also benefit from all the additional support given to in-service teachers. This is also changing and at any moment in time there may be more changes around the corner. In England, there will now be no more teachers trained in ICT, and courses are to be remodelled as Computer Science teacher training [6]. A number of generous bursaries will be available for some well-qualified new entrants to the profession. Typically it has been difficult to recruit new entrants to ICT teaching. This radical change will mean that there will be a new generation of CS-qualified teachers across England; it is too early

to ascertain whether recruitment to CS teaching will be easier than to ICT teaching.

7 A Holistic model

We have considered what teachers claim to need from professional development in the area of CS in schools, and are developing a model based on Kennedy's nine categories that focuses on the following four types of professional development: Cascade, Training, Mentoring and Community of Practice. This will move us some way towards a transformative model. However, from our teacher survey and our own experiences, there appear to be two other types of professional development that would lead further to sustained and long-term change. These are what Kennedy describes as award-bearing (we have renamed this as Accreditation) and Action Research elements of the classification. Incorporating these elements into a model would have long-lasting benefits for teachers, and lead to greater empowerment.

Accreditation Creating professional development courses for in-service teachers that have an award or qualification attached will raise the status of those teachers and enable them to feel that the time spent on their professional development has been worthwhile. By giving teachers these opportunities, which may lead to a professional qualification or indeed academic qualifications, this may aid their progression and career opportunities within school or lead them to be the new teacher educators of the future. This would be very desirable for those teachers who want to progress in this way; however, time and cost are obstacles that stand in the way, especially as it has become more costly to enrol on university courses in England and Wales in recent years.

Action Research In the survey described above, 41% of the teachers responding to the survey indicated that they would find carrying out an action research project either helpful or very helpful as a form of TPD. One of the free comments in the survey referred to the issue of application of ideas:

> *"Most beneficial training has involved both application and accountability - use what you have learned with a class and report back to others"*

We therefore, present a model as shown in Figure 3, as a way of responding to the diverse needs of our teachers, and effecting long-lasting change. The model identifies what we currently offer and what is proposed, utilising six of the categories of Kennedy's framework. As well as being used for in-service training, we hope that this model will feed into our new programme of initial teacher education in Computer Science starting in 2013.

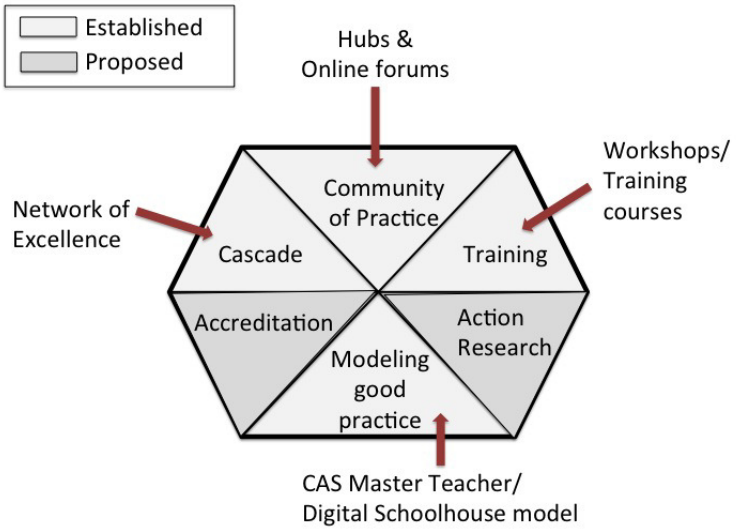

Fig. 3. A developing model for CS teacher education in the UK

8 Conclusion

In the UK, we are moving forwards with enthusiasm towards a future where all children from 5-16 study some form of CS. The situation we are in is not uniform across the four countries that make up the UK, as each establishes their own curricular and awarding bodies. We have recognised that there is a need for diversity in our provision and the government's proposed new programme of study will leave room for interpretation and creativity. However, our survey results show that teachers are in need of support in terms of their professional development and have various constraints relating to how, where and when they can be supported. We have proposed a model that incorporates a range of elements which together should cater for this diversity and give teachers the confidence and empowerment they need. Professional development will not convert *all* ICT teachers into CS teachers but it will raise awareness of what is in the subject of CS and why it is important and it will develop *some* excellent CS teachers from those undertaking training and support. The goal to have 1000 schools offering Computer Science by 2015 seems achievable given the thirst for change experienced to date. In this environment, new teachers who are studying new CS teacher training courses will be valued and encouraged and we hope this will raise the status of teaching in this subject area.

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